



Fabrication of Feedhorn-Coupled Transition Edge Sensor Arrays for Measurement of the Cosmic Microwave Background Polarization



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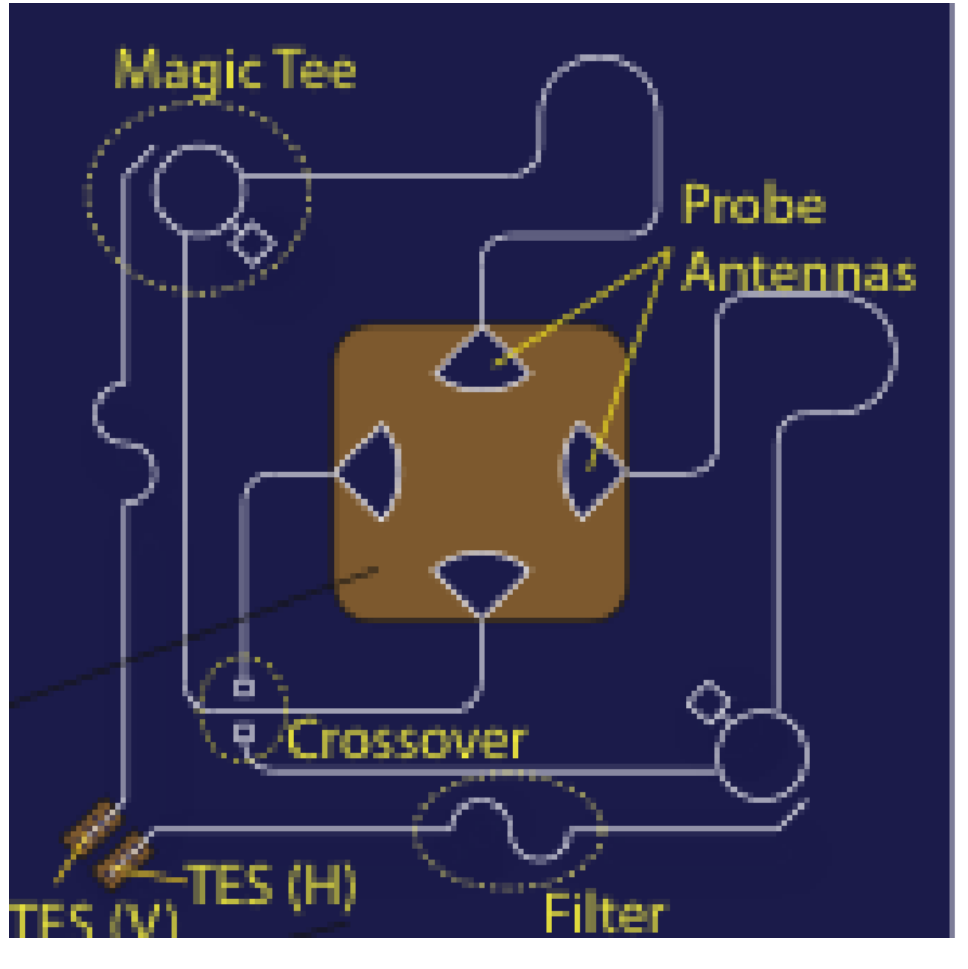
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See talk by D. Chuss: The CLASS Focal Plane Development
Session 5, Thurs, 8:15 – 12:15

Detector Layout

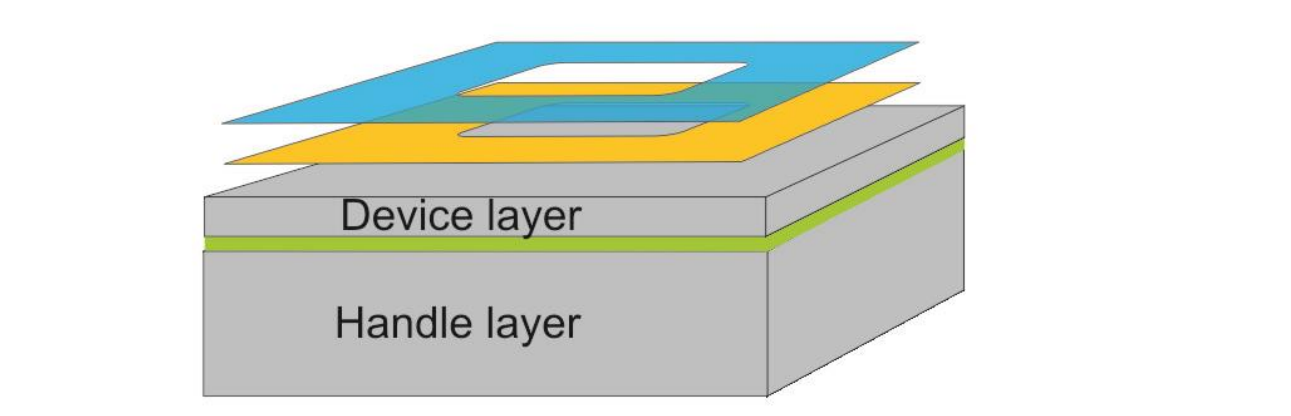


Features:

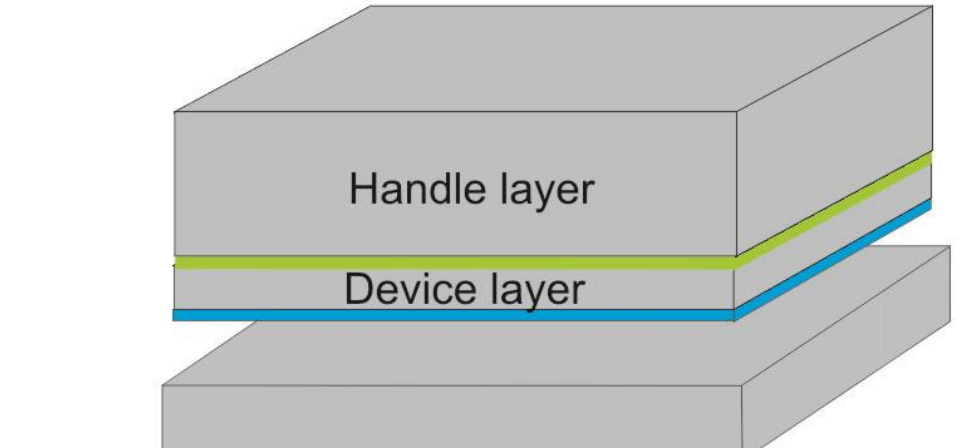
- We have scaled our architecture from single chip design at 40GHz to a 90GHz wafer level modular approach.
- Each module consists of 37 feedhorn coupled dual polarization detectors¹ (72 transition edge sensors).
- A compact design integrates 3D waveguide and planar superconducting microstrip circuitry consisting of a detector wafer, a backshort wafer, and a choke wafer.²
- Low temperature polymer bonding process on the detector wafer enables low-loss single crystal silicon dielectric for superconducting microstrip circuitry and thermal link for MoAu TES operating at 150mK.³
- Indium bump bonded micro-machined silicon structures are used to provide out of band signal rejection.
- Indium bump bonded silicon photonic choke improves feedhorn coupling.
- We are producing 14 modules for two focal planes to support the CLASS Cosmology Large Angular Scale Surveyor Telescope^{4,5} which will survey 70% of the sky from the Atacama Desert in Chile.

Detector Fabrication Process

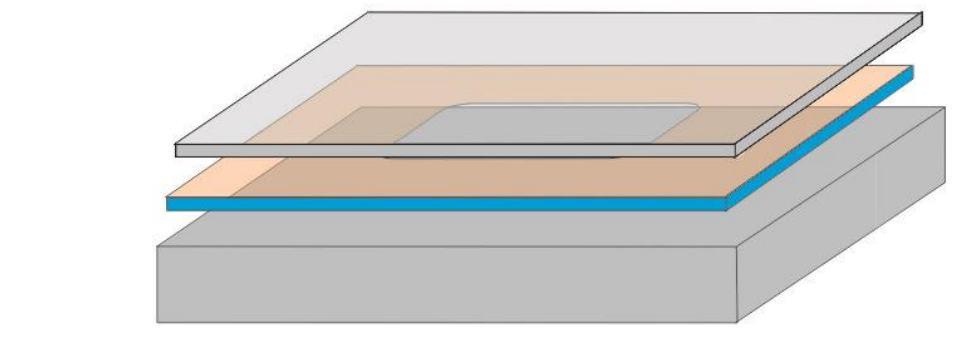
90 GHz Detector



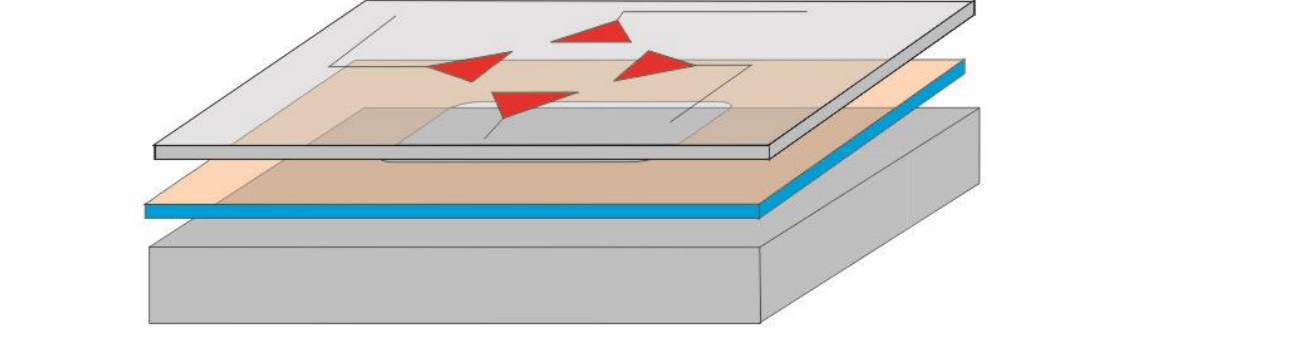
Silicon on Insulator (SOI) wafer: Deposit Nb ground plane and polymer layer for wafer bonding



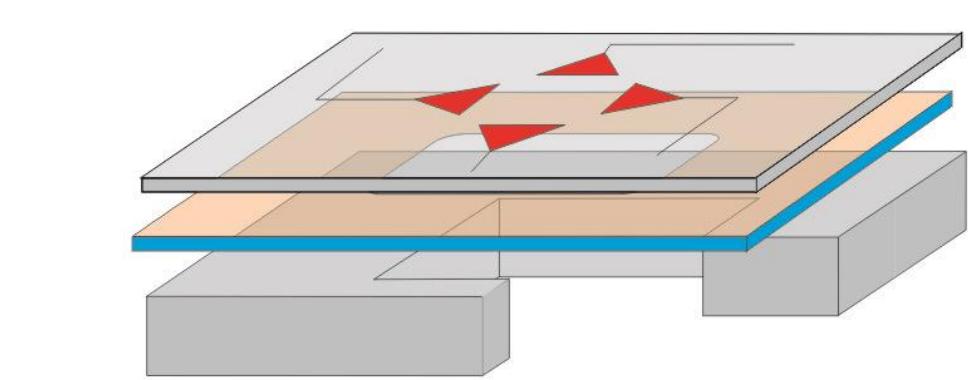
Bond to a low resistivity wafer which will function as an integrated silicon waveguide



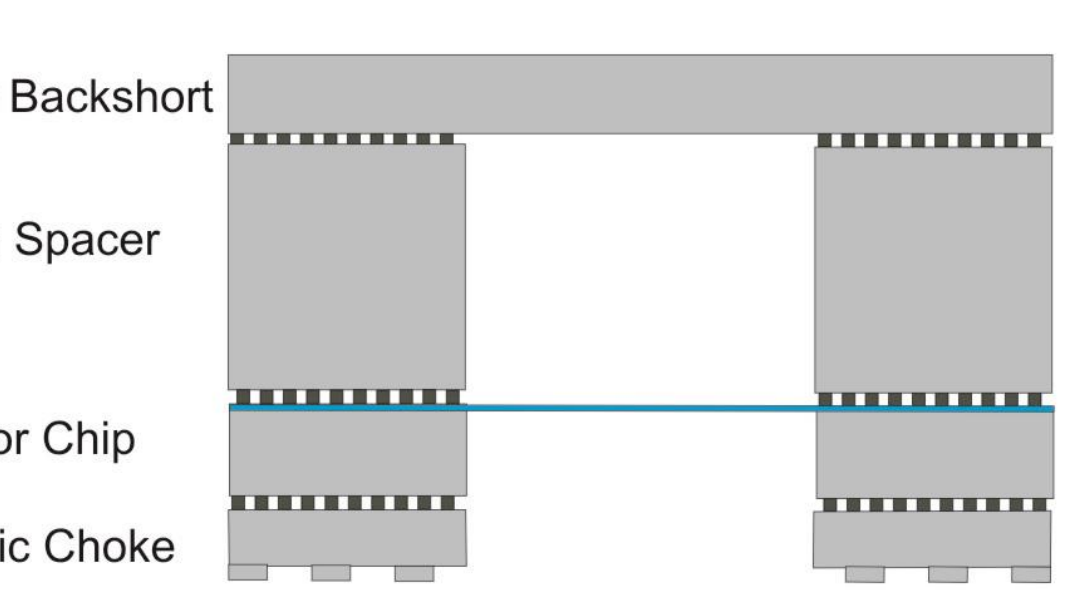
Remove the SOI handle layer and buried oxide. The 5um SOI thermal isolation membrane and the OMT membrane, TES



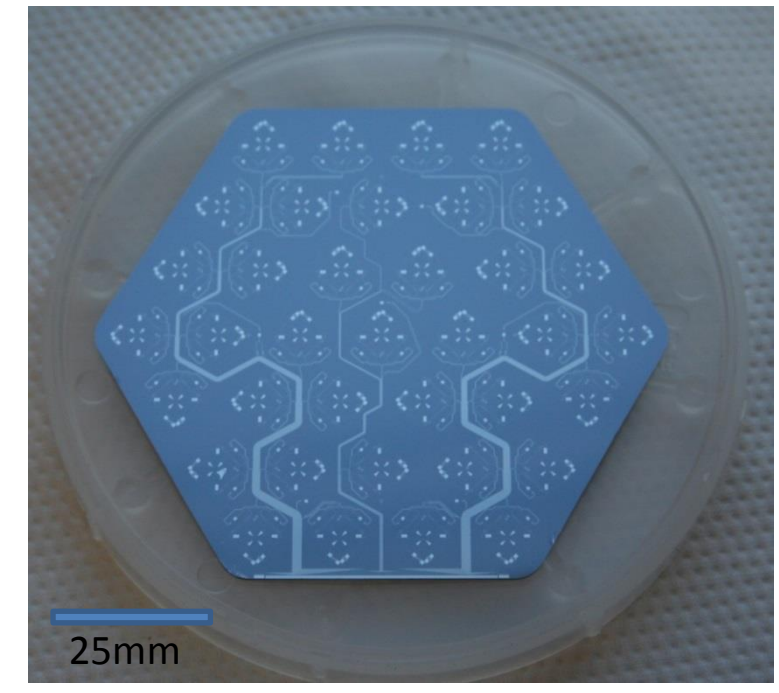
Complete MoAu TES, niobium microstrip, and silicon thermal isolation processing on the device layer side



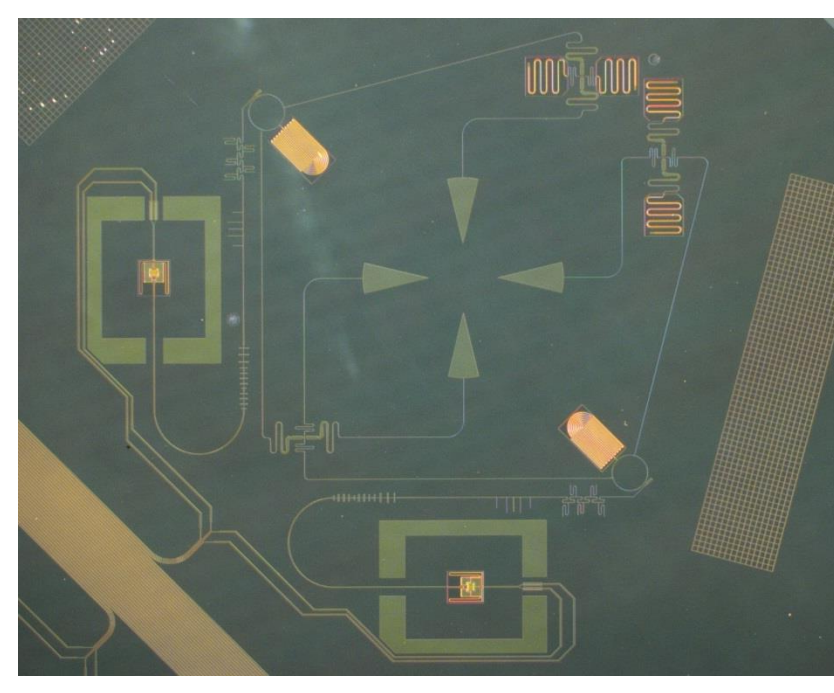
Temporary bond to pyrex wafer(not shown) and deep reactive ion etch (DRIE) to define OMT and release silicon thermal isolation membranes



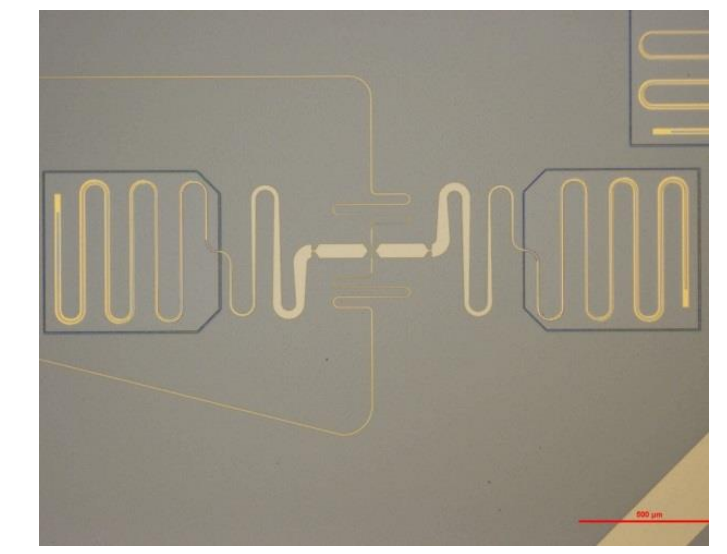
Indium bump bond separately fabricated silicon spacer and silicon backshort chip as well as silicon photonic choke chip.



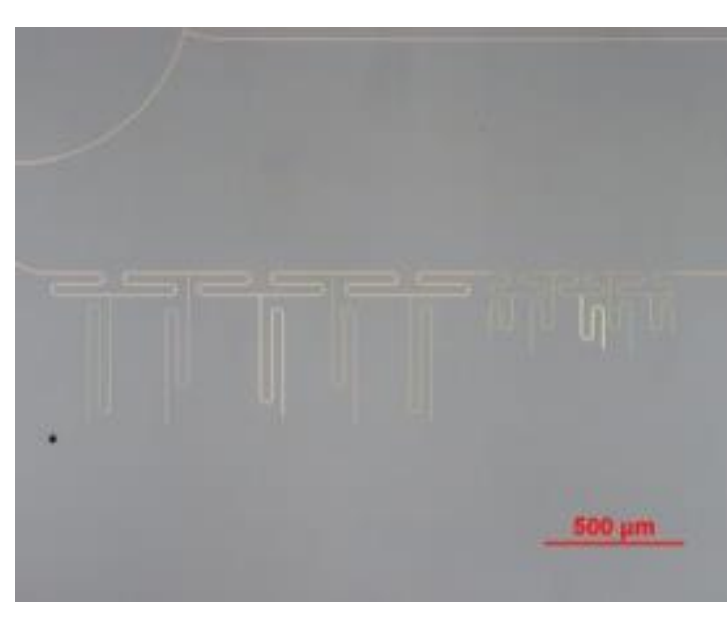
37 element 90GHz detector module



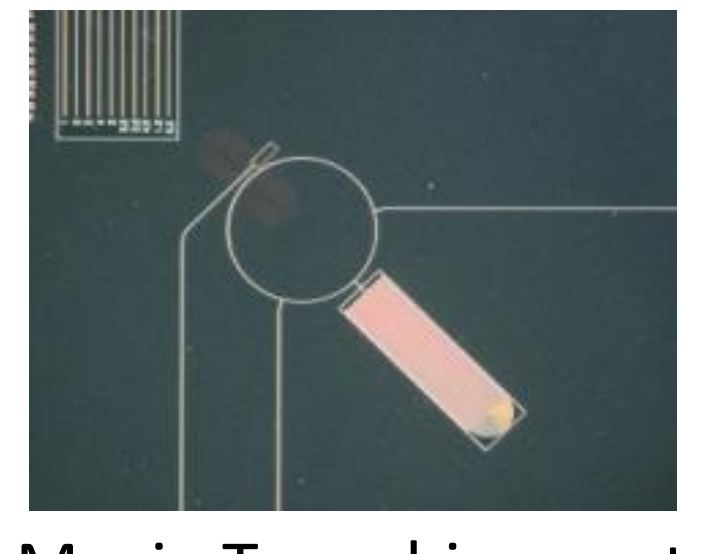
Single dual polarization detector



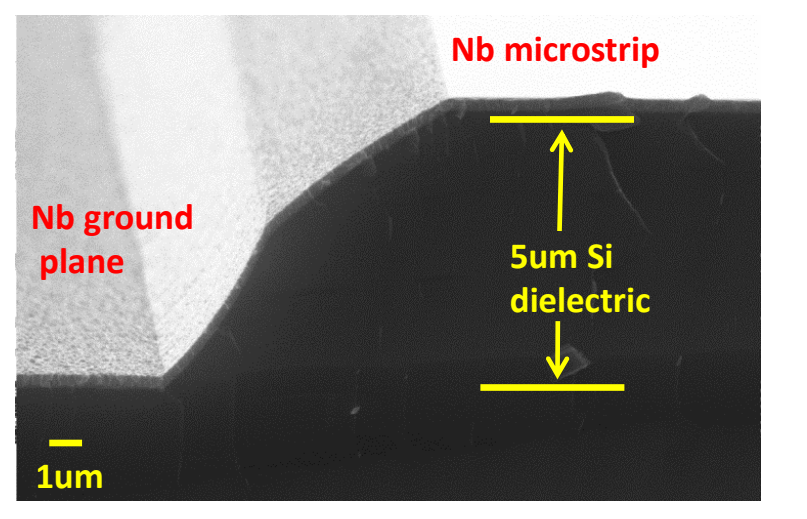
Via-less Crossover⁶



On chip band defining filters

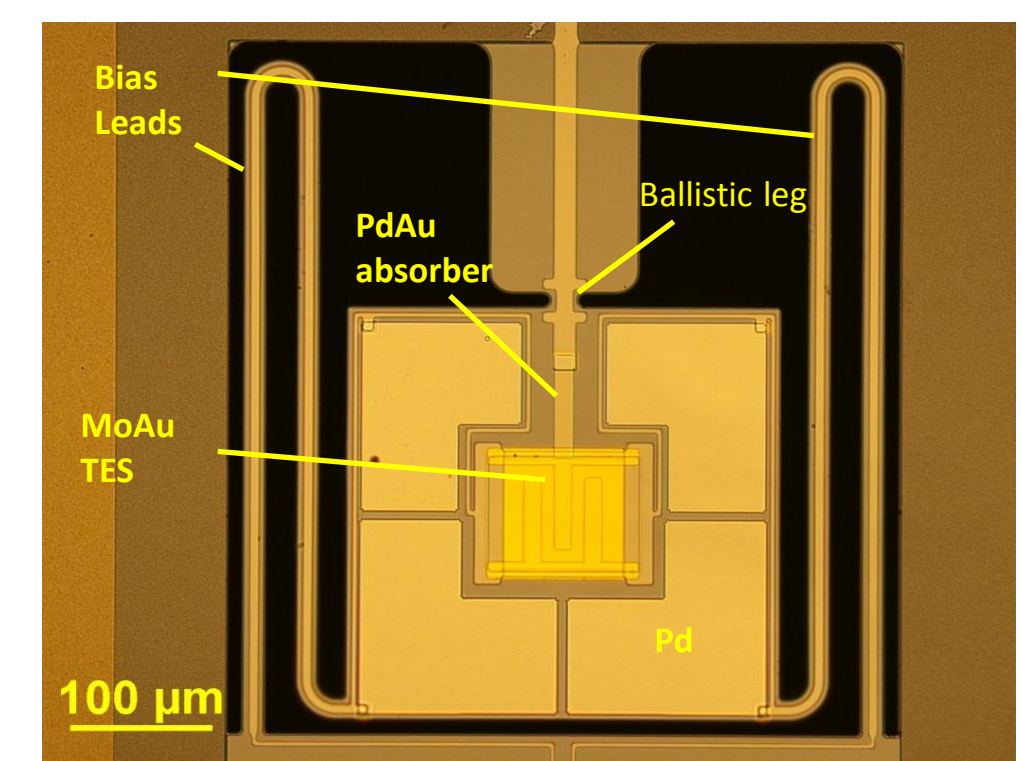


Magic-T combines out of phase signal component & terminates in-phase signal⁷

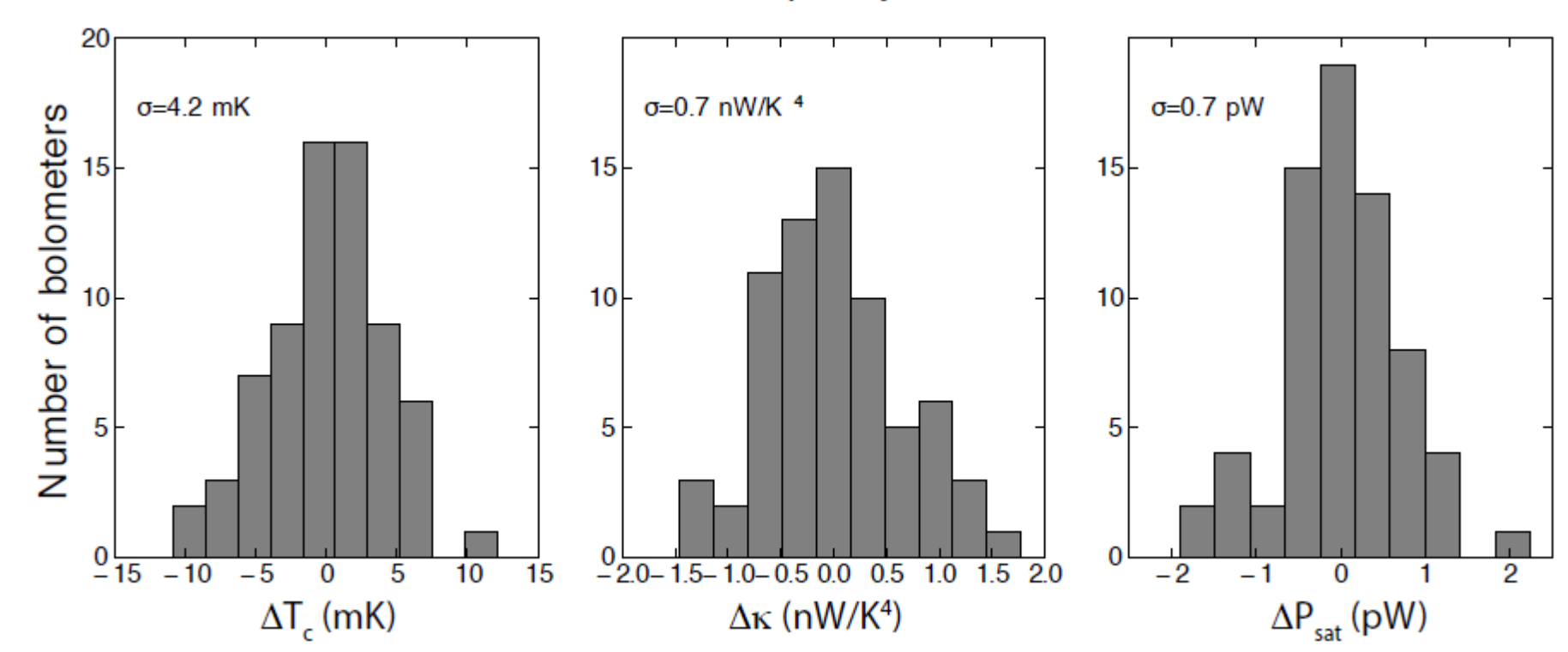


X-section of superconducting niobium ground plane via

MoAu TES bolometer



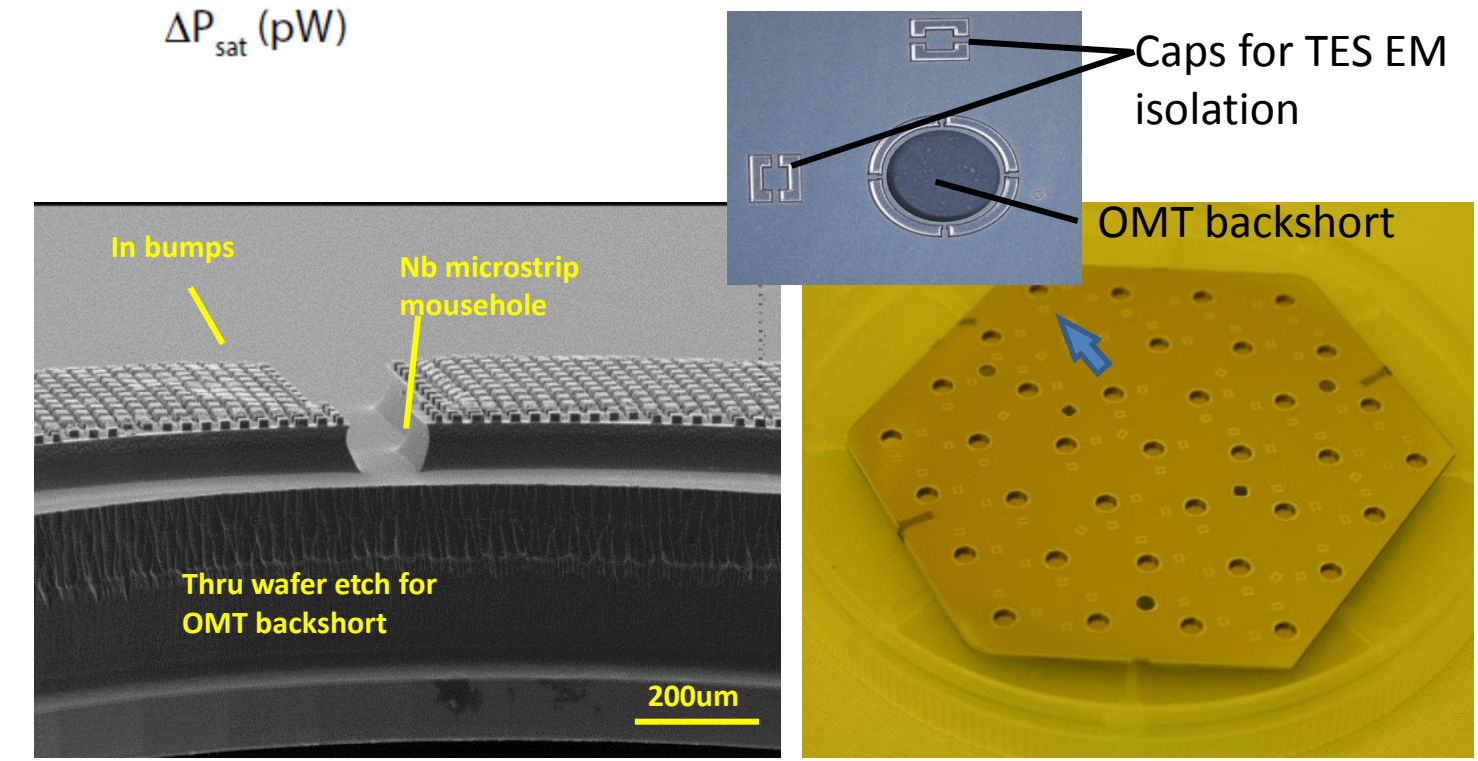
- TES is thermally isolated from bath by silicon membrane.
- Ballistic phonon propagation through short silicon leg improves thermal conductance control in presence of roughened surfaces⁸
- Pd maximizes heat capacity in reduced area.
- PdAu absorber termination electrically coupled to TES operating at 150mK.



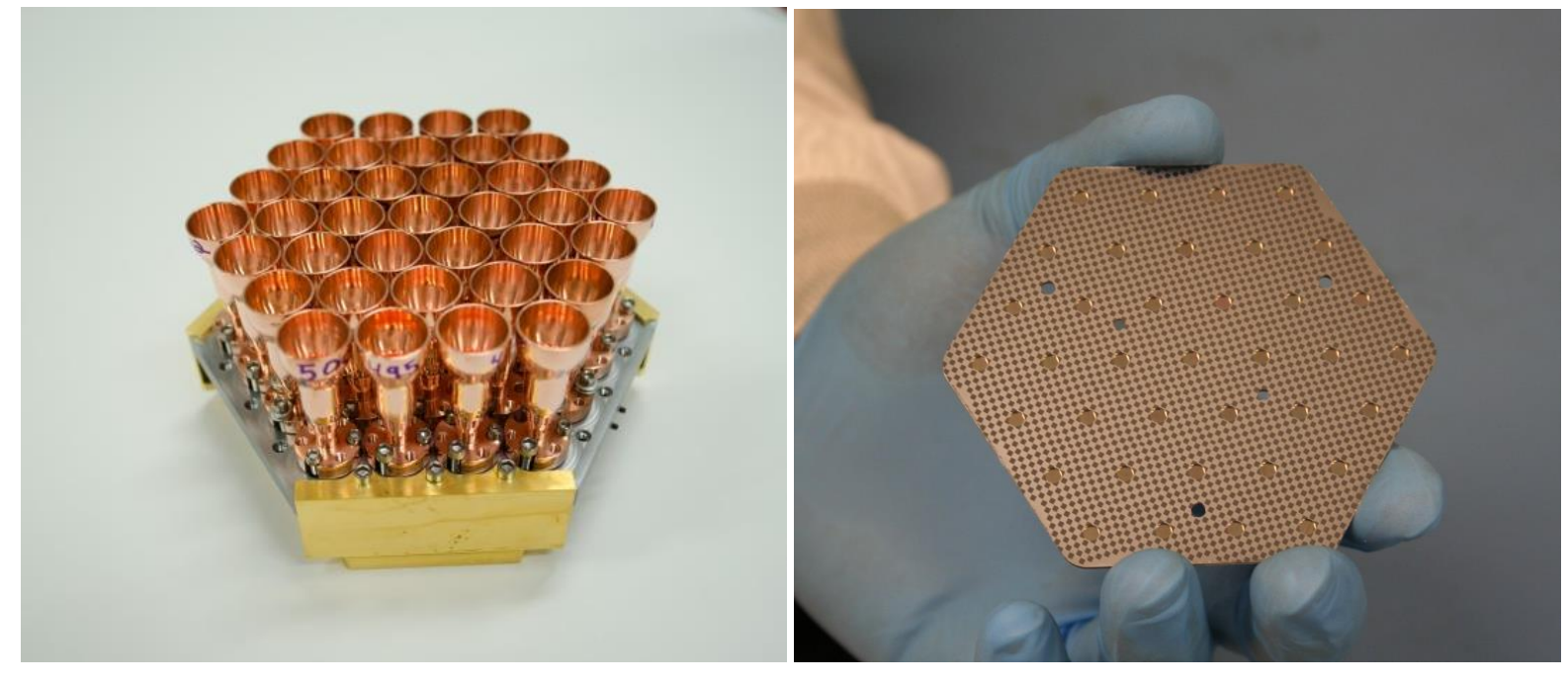
Variation of T_c , thermal conductance, and saturation power for 40GHz focal plane shows good reproducibility of detector thermal properties across five wafers⁹. Our first 90GHz modules are currently in thermal test.

Backshort and EM isolation

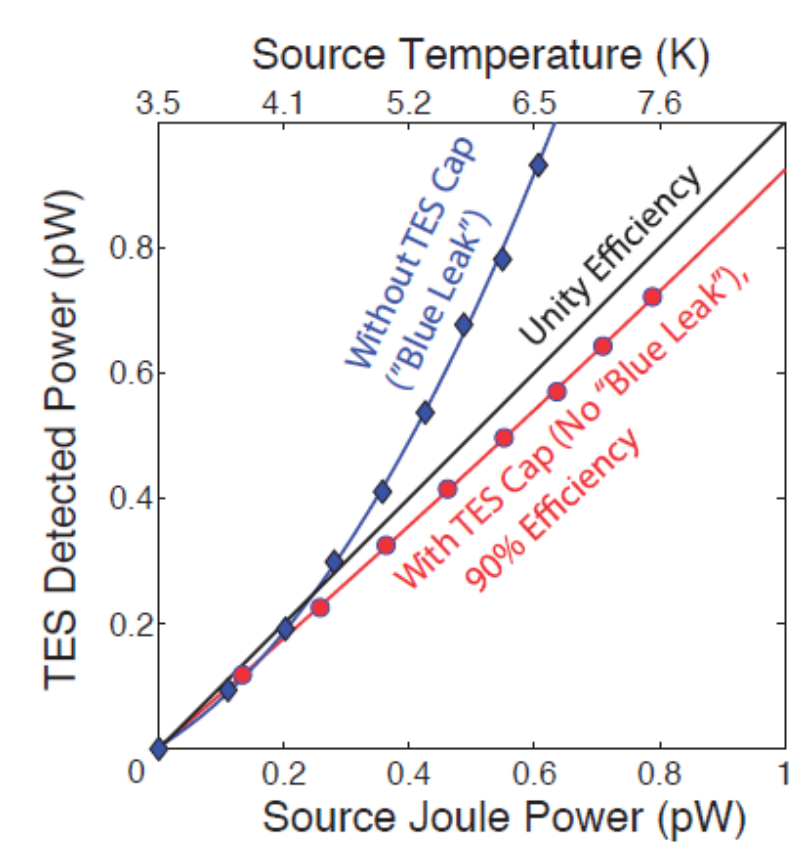
Backshort wafer is flip chip indium bump bonded to detector wafer. Mouse holes allow for Nb microstrip wiring. In bumps are located on top of reliefs which form a cap for TES EM isolation from blue leak.



90GHz module



- Hybridized detector module showing photonic choke pillars micromachined into silicon wafer.
- The choke wafer is indium bonded to the feedhorn side of the detector wafer.
- 7 modules will be incorporated into each of two 90GHz CLASS focal planes



References

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2. K. Denis, et al, "Fabrication of an antenna-coupled bolometer for cosmic microwave background polarization," in Applied Superconductivity Conference (2008).
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7. K. U-Yen, et al, "A broadband planar magic-T using microstrip-slotline transition," IEEE Trans. Microwave Theory Tech 56, 172–177 (2008).
8. K. Rostem et al, "Precision Control of Thermal Transport in Cryogenic Single-Crystal Silicon Devices", Journal of Applied Physics, 115, 124508, (2014);
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